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## EDITED BY

Lutchmie Narine,  
Syracuse University, United States

## REVIEWED BY

Maureen Thompson,  
Syracuse University, United States  
Lisa Olson-Gugerty,  
Syracuse University, United States

## \*CORRESPONDENCE

Bian Lanchun  
✉ blc-sa@mail.tsinghua.edu.cn

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# Environmental measurement study of double-aging neighborhoods under the EPA-S model in China

Chen Mingyu<sup>1,2</sup>, Gan Cao<sup>2</sup> and Bian Lanchun<sup>2\*</sup>

<sup>1</sup>School of Architecture, Tianjin University, Tianjin, China, <sup>2</sup>School of Architecture, Tsinghua University, Beijing, China

The “double aging” problem of the aging population and the simultaneous aging of the community’s physical environment will become a huge challenge in highly urbanized areas of the world, and China’s performance is becoming more and more obvious, affecting the physical and mental health and quality of life of the elderly. Nowadays, the paradigm of solving the double aging problem with the concept of “active aging” is gaining international acceptance, which means the elderly are centered on the design and construction of a community environment that maintains their ability to live independently and promotes active social interaction in urban regeneration. However, existing research still has shortcomings in how to apply the perspective of active aging to establish an indicator system for evaluating the built environment of “double aging” neighborhoods and formulate action strategies. The study constructs a theoretical analysis framework of EPA-S (E-Environment supports, P-Personal abilities, A-Activity behaviors, S-State of healthy and active life) from the perspective of active aging and builds the model based on that. This observational study designed the survey content and collected sample data in four typical double-aging neighborhoods in Beijing for multi-layer linear regression analysis to verify the reliability of the model and the correlation between indicators. It found that the design of the “EPA-S” model has a certain degree of credibility. In addition to personal socioeconomic factors, active living abilities, and material environmental support also have a significant impact on the mental health and happiness of the elderly. Specifically, being more involved in community public affairs and collective cultural and recreational activities, and better improving the quality of public activity venues and service facilities within walking distance of the elderly are related to the elderly maintaining good physical and mental health. The “EPA-S” model established in this study can be used as a reference tool to evaluate the active aging level of “double-aging” neighborhoods. At the same time, the analysis results of each variable also provide important inspiration for formulating specific neighborhoods’ regeneration strategies.

## KEYWORDS

double aging, active aging, older neighborhoods, urban regeneration, China

## Introduction

China is in a period of rapid population aging. By the middle of this century, the elderly will account for more than one-third of the population. At the same time, the stock of approximately 10 billion square meters of old housing in the country is aging at the same time as the residents. Actively solving the comprehensive impact of the

“double aging” problem within the window period is an urgent reality to alleviate the severe challenges that China will face in the next 20–30 years. At present, numerous “double aging” neighborhoods built in the era of welfare housing distribution are generally concentrated in the central urban areas of China’s big cities (1, 2). Since early planning and construction did not take the issue of aging into consideration, the aging community environment and residents are unsuitable for the growing demand for on-site elderly care due to deterioration of physical and mental functions (3, 4). On the other hand, this type of neighborhood, as a familiar environment for the elderly to live in, is also an important factor in maintaining their mental health (5, 6). Compared with young people, the elderly have a stronger sense of spatial dependence on the community environment (7), which can help them establish a sense of identity and belonging, which in turn has a positive impact on health and happiness (8). Solving the problem of double aging requires not only the improvement and transformation of the physical space environment but also the profound contradictions brought about by the complex social structure (9). As a result, more and more countries and regions in the world have gradually realized that by carefully considering the needs of the elderly in urban regeneration, developing cities and communities that support an active aging framework is a new paradigm to solve this problem (10). The term active aging was first proposed by the World Health Organization in 1999 and defined by WHO in 2002 as: “the process of optimizing opportunities for health, participation, and security to enhance the quality of life as people age.” (11). This concept calls on society to view the aging issue positively in a manner and change the inherent concept of the elderly as a social burden and a homogeneous group (12). With the promotion of the concept of active aging, the Aging in Community model was proposed in 2009 (13).

Aging in place can be defined as “one’s journey to maintain independence in one’s place of residence as well as to participate in one’s community” (14), which treats the elderly as the party being provided with services, it only focuses on physical health care and rehabilitation to improve their self-care ability. In the Aging in community model, the elderly and the community have a mutually reinforcing relationship, that is, while creating a good community environment and facility quality to promote the health and happiness of the elderly, the elderly also promote the overall development of the community by participating in social life (15). At the same time, this model emphasizes not only providing services for the elderly, but also creating communities suitable for living and elderly care for all age groups and promoting social inclusion. In 2010, to accelerate the promotion of the concept of active aging around the world, the World Health Organization established a global age-friendly city and community network to promote international experience exchange. Currently, 1,445 cities and communities in 51 countries have joined the network. However, only Qiqihar City in Heilongjiang Province in mainland China is among them. The implementation intensity is far from that in European and American countries. The concept of active aging has been promoted slowly in China. Given that China currently has a high proportion of “young” elderly people who are

fully capable of taking care of themselves (16), many experts have suggested that what these elderly people need is a safe, convenient, and comfortable living environment and participation in activities rather than early admission to nursing homes (17). Therefore, it is necessary way to regenerate the “double-aging” neighborhoods under the framework of active aging, promoting the elderly to maintain an active and healthy living state in the community, and extending the time from aging to disability as much as possible to solve the problem of double-aging. To realize the above path, it is essential to form a clear understanding of the residential characteristics of “double aging” neighborhoods and propose targeted renewal measures. This makes the establishment of a residential environmental evaluation system under the concept of active aging become an important research question of the moment, which is also the core research content of this paper.

## Theoretical background

With the expansion of the concept of “health” from the physical to the psychosocial level in the last century (18) and the shift from state focus to process adaptation (19), the way of looking at diseases has gradually evolved from pharmaceutical medicine to a more comprehensive psychosocial approach (20), and also initiated research around the world on how to delay aging and prevent diseases through active environmental intervention and behavioral adaptation in residential areas (21). Ecological Theory of Aging (ETA) is a representative research result in the above-mentioned research fields. Its core content is about the connection between the built environment and the quality of life of the elderly. This theory was proposed by Lawton and Nahemow in 1973 based on the work of Wohlwill (22). The core content is the Person-Environment Fit model (23), which is about human health and well-being depending on the interaction between personal competence and environmental pressure. The important significance of this model is that it breaks through previous research that focused on the health problems of the elderly on their own diseases and establishes a connection between the living environment and the personal abilities of the elderly. Golant further proposed the residential normalcy model based on the P-E fit model to evaluate the elderly’s adaptation to environmental pressure (24). Applying this model can explain how the elderly’s subjective feelings about the environment affect their decision to age in place or move and expand the cognitive means of the elderly’s connection with the environment, such as understanding the different ways they respond to environmental stress (25). Later, with the proposal of the active aging framework by WHO, American gerontology expert Scharlach integrated life course theory into the ecological theory of aging and proposed an integrated model of aging well. The model includes “6C” elements: Continuity, Compensation, Control, Connection, Contribution, and Challenge. The integrated model of aging well further enriches the methods of recognizing and evaluating the elderly’s adaptation to environmental stress and is of great significance for the planning and formulation of promising policies to improve the physical and social environment. In summary, the development of

the ecological theory of aging provides a theoretical basis and construction ideas for the construction of a “double aging” residential environmental analytical model under the framework of active aging.

In terms of the content dimension design of the analysis model, the existing studies mainly build a localized age-friendly environment evaluation system on the basis of the Global Age-Friendly City Guide published by WHO (26, 27), which includes outdoor spaces and buildings, transportation, housing, social participation, communication and information, etc. In addition, improving connectivity and diversity, as the core content of urban design intervention in residential regeneration to improve the health of the elderly, has also become an important measurement indicator for analyzing the double-aging environment. In 2012, American architect and community design expert Scott Ball pointed out that urban design activities are different from architectural design activities and have the attribute of time as the fourth dimension, which is very suitable for the elderly. Life needs to continue to change over time, so he proposed that urban design means intervening in the community environment to reshape the city as an important way to solve the aging problem (28). The core point of his book is: “Connectivity and diversity are the basic elements that need to be considered in urban design when it comes to age-friendly environmental transformation.” Similar to Scott Ball’s point of view, in 2016, scholars such as Peter Rowe, proposed through field research in “China’s Urban Communities” that urban design should improve connections and provide support. Focus on solving the problem of improving the quality of life of the elderly group, who accounts for a large proportion of old neighborhoods and are most affected by environmental changes (29). Connections refer to changes in urban form, such as opening up closed large blocks and connecting neighborhoods and surrounding block environments with different functions in the urban fabric as a whole to improve the accessibility and pedestrian-friendliness of facilities and services. Supports refer to making changes in the management structure, promoting the flow of information resources between each other through multi-level cooperation, and improving the diversity and complexity of ground-level block functions. In 2019, British public health policy expert Layla McCay and others focused their research on the increasingly serious mental health problems of urban residents around the world based on the WHO’s definition of health and the shortcomings in the field of urban design that pay more attention to physical health and ignore mental health. They summarized the research results in multiple disciplines and constructed the “GAPs” mechanism framework of the urban design affecting mental health through the evidence-based methods, namely Green places, Active places, Pro-social places, and Safe places (30), further clarifying the factors affecting mental health of the elderly in the living environment.

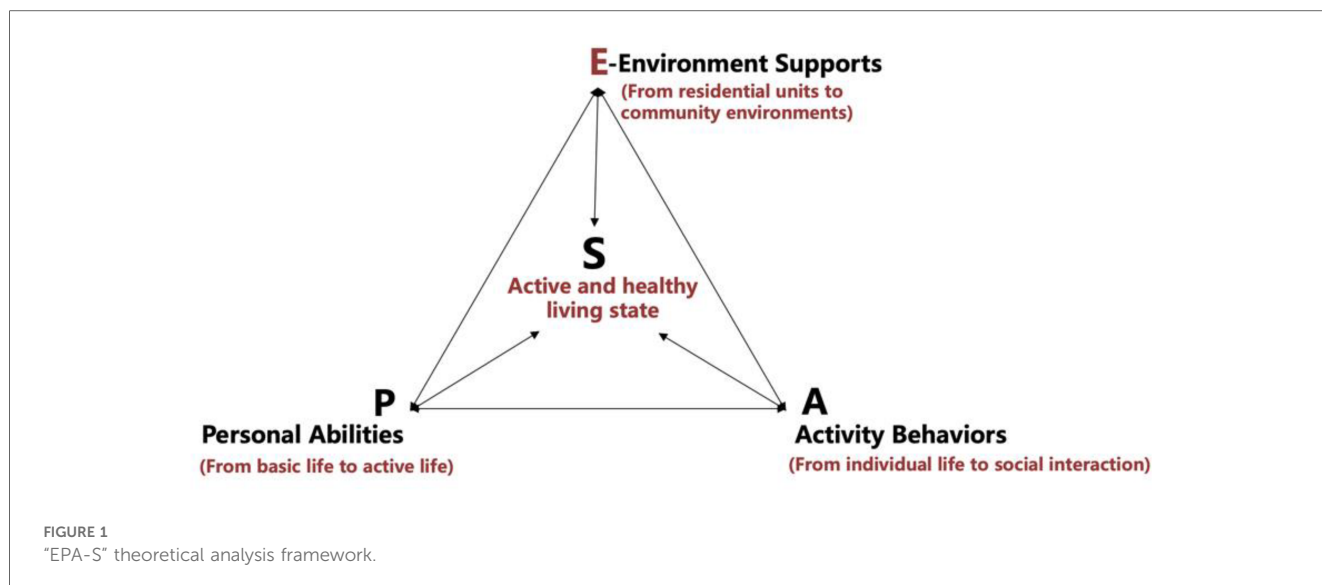
To sum up, the relevant theories and strategies for neighborhood regeneration from the perspective of active aging can be summarized in three aspects: (1) Emphasis on supporting the independent living of the elderly from the places, facilities, and services of the community’s physical and social

environment at multiple spatial scales, maintain social connections and make social contributions and participation. (2) Highlight the role of elderly individuals’ active living abilities in maintaining health and promoting the realization of age-friendly communities. The integrated model of aging well emphasizes that the practice of age-friendly communities should be promoted by improving the active living abilities of the elderly in six aspects, including a positive attitude towards aging, challenging new things, and enthusiasm for participating in public affairs. (3) Participating in physical leisure activities, promoting social connections and interactions, etc. will have a certain role in promoting the mental health and happiness of the elderly, and promoting the occurrence of behaviors such as maintaining social connections and community participation in the elderly is the important content emphasized by the concept of active aging. Therefore, this study refined the “EPA-S” theoretical analysis framework for neighborhood regeneration from the perspective of active aging based on the existing literature review (Figure 1). Among them: (1) “E-Environmental supports”: Emphasis on providing convenient, accessible, diverse, high-quality functional facilities, services, and activity venues for the elderly from residential units to community environments to facilitate independent living and social participation for the elderly; (2) “P-Personal abilities”: Refers to the ability to actively adapt and integrate into the social environment in addition to personal basic life abilities, including the ability to proactively expand social connections with a positive attitude, enrich one’s own life and contribute to society, etc. The content emphasized by the “6C” integrated model for seniors; (3) “A-Activity behaviors”: Emphasis on adding more social interactions, participation, and contribution behaviors on the basis of individual family life, including participation in cultural, sports, and leisure activities, volunteering (4) “S- Active and healthy living state”: the development of the shift from focusing on physical health and disease to focusing on mental health and happiness. In view of the fact that the existing relevant research mainly proposes the regeneration strategy of double-aging neighborhoods through individual survey and lacks quantitative comparative analysis of multiple cases (31). This study attempts to conduct verification analysis of the EPA-S model on different types of residential samples, thereby summarizing the commonalities and differences in residential characteristics and providing a reference for precise policy implementation and program design under the active aging framework.

## Methods

### Study design

The study selected four typical cases of “double aging” neighborhoods in Beijing for objective evaluation and analysis of the physical environment, including the Jiuxianqiao unit compound built in the 1950s and 1960s, the Jinsong unified residential area built in the 1970s and 1980s, Xiaohoucang, a community renovating dilapidated old houses in the late 1980s



and Baimi Community, a historical and cultural district in the old city. The elderly population over 65 years accounted for 37%, 26%, 40%, and 33% respectively, and the layout is shown in Figure 2. From July 2019 to March 2021, the study interviewed an equal proportion of elderly people based on the number of elderly people sampled in each residential area. Approximately 30–60 questionnaires were distributed to each residential area sample, and 224 valid questionnaires were obtained. It should be noted that there is no upper or lower age limit for the elderly surveyed in this study. As long as they are in a state of retirement and have basic self-care abilities and can live independently, they are all research subjects (concentrated in the 55–85 age group). Since the focus of this article is to promote the majority of elderly people who care for themselves at home to maintain a healthy, self-care, active, and happy state in their existing living environment, those elderly people who must stay in nursing homes (disability, dementia, etc.) are not included in the interview object. Therefore, the locations where questionnaires

were distributed during the survey process were mainly concentrated in outdoor public spaces, and there were fewer household surveys. Afterward, a multi-layered linear regression model analysis was performed on the collected subjective and objective data, thereby constructing the relationship between the explanatory variables and the dependent variable of the elderly's mental health (active life status) in the three dimensions of environmental support, personal ability, and activity behavior. The study chose multi-level linear regression because traditional single-level regression can only analyze a single individual or environmental level (32), while the EPA-S model includes two different levels: the individual level (within groups) and the community level (between groups). In part, multi-level linear regression can be used to separate variables at different levels and test the influence of variables in each dimension and their contribution to the explanation of the dependent variable of the elderly's mental health level, so as to obtain a more accurate multi-factor influence mechanism (33).

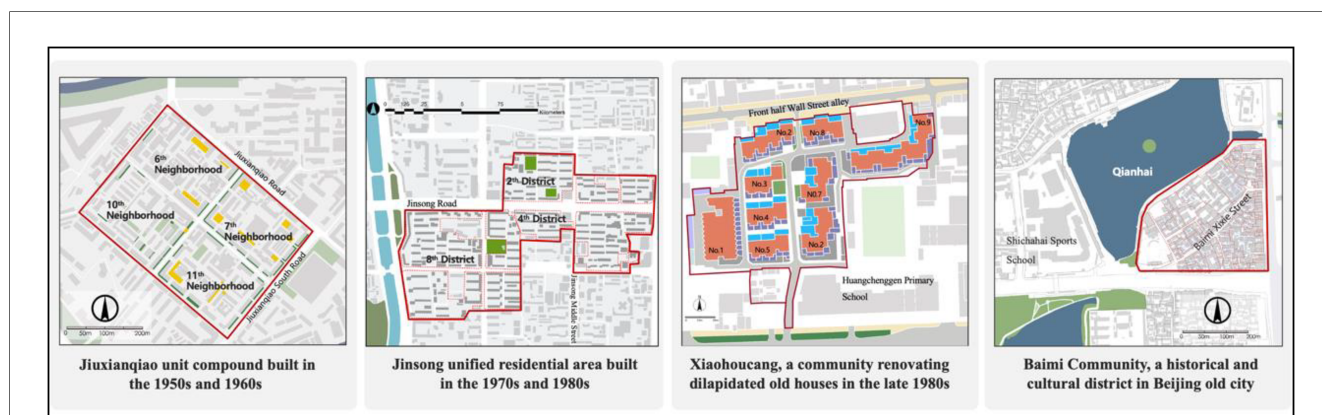


FIGURE 2  
Four typical "double aging" neighborhoods case layout.

## Measures

### S-outcome variables

Promoting mental health is the core goal of active aging. Along with the change in the meaning of health, the concept of mental health has developed from focusing on mental illness to mental well-being (34). It can be summarized as being based on the ability to continue to adapt to environmental pressure, establishing a good relationship with society, and the ability to self-realize and contribute to society, a happy state of being satisfied with life (35, 36). The three points also represent the healthy living status of the elderly under active aging. Therefore, for the dependent variable “S”, that is, in the evaluation process of mental health and happiness, this study mainly selected the WHO-5 Well-Being Index. This scale consists of 5 mental health issues and has proven to have high reliability and validity in numerous mental health studies in different countries and groups (37, 38). It is often used across disciplines due to its ease of operation (39, 40). The content includes: I feel happy, I feel calm and relaxed, I feel motivated, I sleep well, and I am full of interest in life. The evaluation is divided into 6 levels according to the duration of the positive state. The higher the score, the better the subjective evaluation of health status.

### E-environment supports variables

Regarding the design of indicators for the environmental support dimension, existing research mostly evaluates from two aspects: physical and social environment. Among them, the evaluation of the physical environment of neighborhoods is mostly calculated within the 1 km road network buffer zone around the residential area (15-min walkable area), including density, land use mix, floor area ratio, and the convenience and quality of the travel environment, etc. Based on relevant domestic and foreign literature and field surveys, a multi-scale objective evaluation system was constructed from residential units, activity places to residential areas, and urban connections. Include: ① The design of the evaluation index for the quality of housing units refers to the project content on the renovation of the housing building body in the 2019 “Technical Standard for Comprehensive Renovation of Old Urban Residential Areas”, involving aspects such as the single building structure, building facade maintenance, and infrastructure use; ② For the quality of activity places, refer to the public evaluation star model proposed by Varna and Tiesdell (41) that takes into account physical space attributes, management and maintenance, and actual use, as well as the public open space remote desktop evaluation tool (42), forming an evaluation content that includes three aspects: cleanliness, safety, and activity; ③ The relationship between residential areas and cities focuses on evaluating the accessibility and diversity of various service facilities (28, 29). There are three ways to score indicators: scoring directly on site based on standards, scoring based on on-site surveys combined with resident feedback, or combining with GIS data analysis. The contents of each indicator are scored according to consistent standards to judge the severity of the problem (basically no

problems are assigned 0 points, and there are some problems and serious problems are assigned 1 and 2 points). It means that the greater the total score, the more problems the physical environment of the residential area is exposed to in terms of supporting active aging, which aims to improve the operational convenience and question directness of the survey.

It is worth mentioning here that in recent years, research has gradually included individuals’ subjective perception of the physical environment of the neighborhoods as a variable in multi-level regression analysis because the subjective perception of the environment is considered to be closer to actual psychology, behavior, and health results (43). It mainly includes satisfaction with the environment and facilities. Therefore, this study adopted a satisfaction evaluation on the perception of the physical environment, covering different scales from housing to buildings, inside and outside the community. The five-point Likert scale used in the survey was tested during the pre-survey process. Finally, in terms of social environment perception, in addition to considering neighborhood relationships, it also involves evaluations that reflect residents’ integration into society, participation in community activities and public affairs, etc.

### P-person abilities variables

The socioeconomic conditions of the elderly are related to their mental health and well-being and are used as control variables in multilevel linear regression models for statistical analysis. Therefore, this study combines the “double aging” problem and expands the control variable indicators of existing studies. In addition to the socioeconomic foundation, it also pays attention to the senior living status in the residential area, and summarizes it as an indicator of personal basic living ability: ① Social and economic basis, such as age, education, occupation, income, housing property rights, and area, etc.; ② Elderly care living conditions, such as personal mobility, self-reported health, family structure; ③ Connection with the residential area: length of residence and reasons. The investigation of personal active living abilities under this dimension refers to the concept of seniors proposed by Scharlach (13), which emphasizes the functional level (such as good health and, a high level of physical, cognitive, and social functions), and the interpersonal level (having close relationships, helping others, being respected, having a harmonious relationship) and attitudinal level (positive attitude, accepting age changes, enjoying life, being happy, religious, having a sense of purpose). The design includes specific indicators from three aspects: the elderly’s adaptation to the environment, attitude towards aging, and social participation: ① Adaptability to the living environment, such as long-term living intention, social contact, and maintenance of social relationship networks; ② Perception of the aging process, such as attitude towards accepting new things, meeting challenges or coexisting with young people, affirmation of self-worth, perception of society’s attitude towards the elderly, etc.; ③ Social participation and re-employment ability, such as social connections, attitudes and performance in participating in community cultural and sports activities, social public affairs, re-employment, etc.

## A-activity behaviors variables

Based on the existing activity log questionnaire (44), combined with the main content of the active aging theory and the observation of the pre-investigation process, this study divided the activities of the elderly into 5 categories and 18 sub-categories to record their daily activities and behaviors (including behavior type, start and end time). In the specific statistical analysis, in order to further reflect the extent to which the behavior promotes active and healthy elderly living conditions, the activity content of each subcategory is graded on a quality scale of 1–3. The higher the score, the higher the positivity of the behavior. Among them, the content of Level 1 activity quality mainly includes work performed at home, basic leisure activities at home (such as watching TV, etc.), and out-door errands (shopping, consumption, etc.). Behaviors of Level 2 activity quality mainly include playing with mobile phones at home, walking and chatting outside, and re-employment. These activities will promote the elderly to maintain contact and social interaction with the outside world to a certain extent. Finally, the behavior of level 3 activity quality mainly involves engaging in activities related to personal interests and hobbies and making a certain contribution to society, participating in various leisure activities, sports, taking the initiative to further study, being a community volunteer, etc. It emphasizes the affirmation of one's value in a wider range of social participation, and actively faces the lifestyle of old people's life. Finally, the duration data is summarized into six types based on H-1 (work at home), H-2 (general leisure at home), H-3 (high-quality leisure at home), and O-1 (work outside the home), O-2 (general leisure outside the home), O-3 (outing for high-quality leisure or work). Coding factors and operation of EPA-S evaluation index system are shown in Table 1.

## Statistical analyses

Referring to existing relevant literature on the order and specific content of adding independent variables in the calculation process of multi-level linear regression models (45–49), the model levels and content of this study include: Model 1 is an empty model, and Model 2 adds control variables (age/political affiliation/educational status/residence property rights/house type/monthly income/housing area/family situation/length of residence/reason for residence), Model 3 adds personal active life ability (long-term residence intention/interpersonal network connections/interactions with young people/personal importance to society/perception of social participation channels/importance of interpersonal communication/importance of community cultural and sports activities/satisfaction of cultural and sports venue needs/willingness to participate in community public affairs/re-employment status), Model 4 adds subjective perception of the physical environment [overall satisfaction/community surrounding environment satisfaction/satisfaction with the environment in the community/satisfaction with the environment within the building (in the courtyard)/satisfaction with the housing environment], model 5 adds social environment perception (identity of neighborly mutual assistance/number of acquaintances in the community/sense of

community belonging/trust of community residents/trust in the subdistrict office/trust in the neighborhood committee/trust in the resident representative), model 6 adds the activity duration variable (duration of labor activities at home/duration of general leisure activities at home/duration of high-quality leisure activities at home/duration of out-of-home errands/length of general leisure activities outside/length of high-quality leisure or work activities outside), Model 7 adds objective evaluation variables of the physical environment (environmental quality around the residential area/environmental quality within the residential area/housing environment quality/connection between the residential area and the city).

## Results

### Sample characteristics

Judging from the control variables, that is, the survey results on personal basic living abilities, the elderly samples in all residential areas are generally around 70 years old, mostly with junior high school education, with a monthly income of 3,000–5,000 yuan, and a housing unit area of about 44 square meters. Elderly people who take care of themselves account for the highest proportion, tending to have a healthier overall perception of their own health. The family structure is mainly 2–3 people, and they have lived there for nearly 20 years. The internal difference is reflected in the fact that there are more elderly people in the 10th neighborhood of Jiuxianqiao than in other residential areas, and their mobility is relatively poor. In addition, all the interviewed elderly people in Baimi Community and Jiuxianqiao Neighborhood have lived for more than 20 years, while Jinsong Residential Area is relatively short. In terms of personal active living ability, the elderly are generally more willing to continue living in old neighborhoods, show strong enthusiasm for social participation, and are eager to interact with others. At the same time, they tend to engage in activities with young people and learn new things. However, the enthusiasm of the elderly to participate in community cultural and sports activities is relatively low, and they tend to believe that the community does not meet their activity needs. In terms of the differences within the residential area, the long-term living intention of Jiuxianqiao residents is significantly lower than that of other residential areas. However, a higher proportion of them have participated in social and public affairs after leaving their jobs, and they pay more attention to communicating with others. Meanwhile, Baimi Community and Jinsong District 2 are relatively more willing to participate in community public affairs, more affirmative of their own value, and show a stronger desire to interact with young people, learn and accept new things.

In terms of the independent variable—environmental support evaluation, there are obvious gaps in the physical and environmental quality of residential areas. Those with higher scores and poorer environmental quality include Jiuxianqiao Neighborhood 11 and Jinsong District 4. Although these two communities were built in different years, they both lacked follow-up updates and maintenance projects after their completion. The

TABLE 1 Coding factor and operation of EPA-S evaluation index system.

Dimension	Criterion layer	Index level	Operational way
E-Environment Supports-objective evaluation variables of the physical environment	Housing Environment Quality	(HE1) Construction Standard	Score directly on the spot according to the criteria
		(HE2) Building Façade Maintenance	Score directly on the spot according to the criteria
		(HE3) Infrastructure Condition (water supply and drainage, etc.)	On-site and combined with the feedback of residents score
		(HE4) Building Structure	On-site and combined with the feedback of residents score
		(HE5) Yard/Building Travel Accessibility	On-site and combined with the feedback of residents score
	Activity Site Quality	(AS1) Cleanliness (visual level)	Score directly on the spot according to the criteria
		(AS2) Sense of safety (perception level)	Score directly on the spot according to the criteria
		(AS3) Vitality (use level)-physical exercising facility	Score directly on the spot according to the criteria
		(AS4) Vitality-open space facility (seating)	Score directly on the spot according to the criteria
		(AS5) Vitality-support facility (rain shelter, toilets, lighting, etc.)	Score directly on the spot according to the criteria
	Relationship between residential area and city	(RC1) Boundary form	Score directly on the spot according to the criteria
		(RC2) Accessibility to amenities outside the compound	Field scoring combined with GIS data
		(RC3) Perfection of service facilities for the aged	Field scoring combined with GIS data
	E-Environment Supports-subjective perception of the physical environment	Multi-scale environment Satisfaction	(ES1) Overall satisfaction with residential life
(ES2) Neighborhood/community surrounding			Questionnaire Survey
(ES3) Inside neighborhood/outside courtyard environment satisfaction			Questionnaire Survey
(ES4) Building/courtyard environment satisfaction			Questionnaire Survey
(ES5) Housing unit satisfaction			Questionnaire Survey
E-Environment Supports-subjective perception of the social environment	Neighborhood relations	(NE1) Identity of neighborly mutual assistance	QS: I think “a close neighbor is better than a distant relative.”
		(NE2) Number of acquaintances in the community	QS: How many people do you meet and greet in your community?
	Neighborhood attachment	(NA1) Sense of community belonging	QS: To feel like I belong to the community, a part of the community
		(NA2) Trust of community residents	QS: Most of the people in the neighborhood are trustworthy
		(NA3) Trust of sub-district office	QS: Sub-district office trust
		(NA4) Trust of community neighborhood committee	QS: Community neighborhood committee trust
		(NA5) Trust of resident representatives	QS: Trust of resident representatives such as building leaders
P-Personal Abilities-elderly basic living ability	Socioeconomic base	(SB1) Gender	Questionnaire Survey
		(SB2) Age	Questionnaire Survey
		(SB3) Politics status	Questionnaire Survey
		(SB4) Education	Questionnaire Survey
		(SB5) Monthly income	Questionnaire Survey
	Support statement	(SS1) House type	Questionnaire Survey
		(SS2) Type of work before retirement	Questionnaire Survey
		(SS3) Action Capacity	Questionnaire Survey
		(SS4) Life partner	Questionnaire Survey
Links to settlements	(LS1) Duration of residence	Questionnaire Survey	
	(LS2) Reasons of living here	Questionnaire Survey	
P-Personal Abilities-elderly active living ability	Adaptability to the living environment	(AE1) Long-term residence intention	QS: Long-term residence intention
		(AE2) Network maintenance	QS: I don't feel like social connections are what they used to be
	Perception of the aging process	(PA1) Communicate with young people	QS: I enjoy being around young people and accepting new things
		(PA2) Social service willingness	QS: I feel that society still needs me, I can still contribute to society
		(PA3) Access to social participation channels	QS: I feel like I have ample channels for social participation
		(PA4) The need to interact with people	QS: Meeting people is important to me

(Continued)

TABLE 1 Continued

Dimension	Criterion layer	Index level	Operational way
	Social participation and re-employability	(SP1) Participate in cultural and sports activities	QS: I think it's important for me to get involved in community activities
		(SP2) Event space demand	QS: Activities organized by the community meet my needs
		(SP3) Willingness to participate in public affairs	QS: Willingness to participate in public affairs in the community
		(SP4) Willingness to work after leaving the job	QS: What have you done in the following jobs after leaving office
A-Activity Behaviors	Busy at home (H-1)	The time of cooking/cleaning up/taking care of parents, children	Activity Diaries Survey
	Leisure at home (H-2)	The time of short rest/watch TV/play electronic equipment/singing, etc.	Activity Diaries Survey
	Errands (O-1)	The time of shopping/pick up the child/take care of parents	Activity Diaries Survey
	Hang out (O-2/O-3)	The time of walking/chatting/playing chess, cards/do leisure activities/sports, etc.	Activity Diaries Survey
	Work outside (O-2/O-3)	The time of community volunteer work/re-employment	Activity Diaries Survey
S-Active and healthy living state	WHO-5 Index	I have felt cheerful in good spirits	Questionnaire Survey
		I have felt calm and relaxed	Questionnaire Survey
		I have felt active and vigorous	Questionnaire Survey
		I woke up feeling fresh and rested	Questionnaire Survey
		My daily life has been filled with things that interest me	Questionnaire Survey

second echelon of scores is the Xiaohoucang and Baimi communities. Both of these residential areas are characterized by self-built extensions occupying public spaces in the courtyards. The conditions of public activity venues within the residential areas are poor. Jiuxianqiao District 10, Jinsong District 2, and Jinsong District 8 have the lowest scores and higher material environment quality. The overall satisfaction of the elderly residential group with the living environment is close to the general level and shows obvious differences, which is reflected in the fact that the satisfaction with the environment around the community is generally higher than the physical environment at other scales. Among them, the elderly in the 11th neighborhood of Jiuxianqiao have the worst evaluation of overall satisfaction, followed by the 10th neighborhood in Xiaohoucang and Jiuxianqiao, while the elderly in the three communities of Jinsong are generally satisfied with the living environment. In terms of subjective perception of the physical environment, the elderly have high evaluations in terms of neighborhood relations and community belonging. They generally tend to agree that they are members of the community. The number of residents they know and greet is more than 30. At the same time, they also show characteristics of relatively low trust evaluation of community committees. In terms of differences within residential areas, the elderly people interviewed in Baimi Community showed a relatively stronger sense of community belonging, and their trust in the dean, community committees, and sub-district offices was also higher than in other residential areas.

On the other hand, the study found that the elderly living in poor housing conditions spent relatively longer time outside for activities. The elderly spent more than 8 h indoors while awake, and indoor leisure activities activity behavior accounts for the least

proportion. At the same time, O-2 general outdoor leisure activities (walking, chatting, etc.) accounted for the highest proportion of the total outdoor activity duration, with an average duration of 3 h. And the elderly spend about an hour every day going out to do errands (buying groceries, picking up children, etc.). Judging from the differences within the residential areas, the duration of indoor activities for the elderly in Baimi Community and Jiuxianqiao No. 11 is relatively short, but the duration of O-2 activities is relatively longer. The most active O-3 activities (dancing, participating in community volunteer activities, etc.) occur more frequently in Jinsong District 2 and Jiuxianqiao 10th Street. Finally, the mean data of the dependent variable (WHO-5 Well-Being Index) shows that the self-evaluation of the elderly was generally at the average level, with the worst result in the evaluation of things that were interesting in daily life. In addition, there are obvious differences between the residential samples. Among them, the mental health level of the 11th neighborhood of Jiuxianqiao, Jinsong District 4 and Xiaohoucang is relatively low, while the mental health level of Baimi Community, Jinsong District 2 and 8, and Jiuxianqiao District 10 is relatively good, which indicates that the mental health level of residential areas with poor living conditions is relatively low.

## Correlational analysis

The collected subjective and objective data were analyzed using a multi-layer linear regression model. The results are shown in Table 2. First, in the random effects model, the intraclass correlation coefficient (ICC) is 0.119, which means that 11.9% of



TABLE 2 Simulation results of multi-layer linear regression model.

Random effects	Model 1 (empty model)		Model 2 (adds control variables)		Model 3 (adds personal active life ability)		Model 4 (adds subjective perception of the physical environment)		Model 5 (adds social environment perception)		Model 6 (adds the activity duration variable)		Model 7 (adds objective evaluation variables of the physical environment)	
	Variance	Std. dev.	Variance	Std. dev.	Variance	Std. dev.	Variance	Std. dev.	Variance	Std. dev.	Variance	Std. dev.	Variance	Std. dev.
Intercept	0.120	0.089	0.411	0.303	0.287	0.212	0.165	0.140	0.149	0.131	0.157	0.137	0.000	0.000
residual	0.906	0.087	0.768	0.079	0.649	0.069	0.621	0.067	0.605	0.067	0.605	0.068	0.602	0.067
Pseudo R squared	0.119		0.314		0.414		0.443		0.485		0.493		0.568	
			0.195		0.101		0.029		0.042		0.008		0.074	

the variance of individual mental health comes from the differences between residential sample environments. The Durbin–Watson test value of 2.024 is also certain that the residuals are independent of each other. Seeing from the results of  $R^2$ , the degree of explanation of psychological well-being of the model that continuously adds new variables is constantly improving, and finally reached a high explanation degree of 56.8%. It can be said that the evaluation index system constructed by this research has qualified credibility and practical application value. From the contribution values of each model to the change in  $R^2$ , it can be found that in addition to the control variables, personal active life ability and material environmental support have the largest contribution values, which shows that there is a close connection between them and mental health and happiness.

The coef. and  $t$  value results of the variables in each model are (Table 3): the correlation coefficients and significance levels of the age, income, mobility, housing type, and length of residence variables in Model 2 (control variables) are higher. Therefore, it is necessary to pay attention to the differences between the elderly groups in the research and practice of “double aging” neighborhoods. In Model 3 (personal active living ability), the variables of long-term residence intention and willingness to participate in community cultural and sports activities have a stronger relationship with mental health, and the significance level is also high. This shows that it is necessary to pay attention to how to promote the elderly to participate more in community sports and sports activities in the construction of age-friendly communities. The overall environmental satisfaction of the residential area in Model 4 (subjective perception of the physical environment) and the trust in the street factor in Model 5 (subjective perception of the social environment) have higher correlation and significance with the mental health level of the elderly, thus strengthening the connection between street level and residential areas, etc. In Model 6 (activity duration), the activity duration of category O-3 (the most active) has a significant impact on the mental health of the elderly. Therefore, promoting the elderly to participate in community public affairs, volunteer services, and collective recreational activities is an important content that needs attention in the renewal of double-aging residential areas. Finally, In Model 7 (physical environment), the quality of activity space in and around residential areas, and the relationship between residential areas and cities are more closely related to mental health variables. It shows that improving the quality of public activity venues in the neighborhoods and focusing on the community scale meeting the basic living and elderly care needs is crucial to the development of physical and mental health.

## Discussion

Nowadays, a variety of models to deal with aging (home-based elderly care, community elderly care, institutional elderly care, etc.) coexist. The key to the city’s future aging-friendly regeneration policy design is to judge these models to clarify the path and method that should be adopted. Relevant enterprises and

TABLE 3 Simulation results of multi-layer linear regression model.

	Model 1 (empty model)		Model 2 (adds control variables)		Model 3 (adds personal active life ability)		Model 4 (adds subjective perception of the physical environment)		Model 5 (adds social environment perception)		Model 6 (adds the activity duration variable)		Model 7 (adds objective variables of the physical environment)	
	Coef.	t Value	Coef.	t Value	Coef.	t Value	Coef.	t Value	Coef.	t Value	Coef.	t Value	Coef.	t Value
<b>Fixed effects</b>														
Intercept	-0.041	-0.788	-0.199	0.867	0.149	0.892	-0.114	0.913	-0.423	0.685	-0.329	0.756	0.332	0.751
<b>Basic info</b>														
Gender: Male			0.008	0.955	-0.129	0.328	-0.122	0.350	-0.065	0.619	-0.033	0.809	-0.022	0.871
Political status: Communist Party member			0.261	0.497	0.324	0.371	0.303	0.400	0.368	0.310	0.327	0.372	0.323	0.378
Educational background			-0.114	0.115	-0.112	0.100	-0.105	0.120	-0.112	0.096	-0.094	0.169	-0.109	0.108
Monthly income			-0.222	0.012	-0.229	0.006	-0.187	0.022	-0.193	0.018	-0.187	0.025	-0.206	0.014
House type: Unit			-0.609	0.366	-0.693	0.244	-0.561	0.261	-0.488	0.313	-0.378	0.440	-1.033	0.017
House type: Shared			-1.376	0.001	-1.309	0.001	-1.410	0.000	-0.139	0.001	-1.358	0.001	-0.137	0.001
Type of job before retirement: employee			0.445	0.519	0.486	0.454	0.708	0.269	0.814	0.202	0.691	0.286	0.604	0.351
Type of job before retirement: self-employed			1.163	0.307	1.688	0.113	1.863	0.075	1.959	0.067	1.653	0.129	1.486	0.171
Action capacity			0.207	0.002	0.186	0.004	0.187	0.003	0.181	0.005	0.166	0.010	0.164	0.011
Duration of residence			0.060	0.420	0.086	0.215	0.101	0.140	0.128	0.064	0.140	0.044	0.130	0.060
Reason of living: Flat subdivision			-0.214	0.664	-0.102	0.824	-0.251	0.579	-0.145	0.748	-0.318	0.507	-0.328	0.492
Reason of living: Married to move in			-0.788	0.143	-0.713	0.160	-0.772	0.121	-0.692	0.169	-0.925	0.080	-1.033	0.051
Active life ability														
Long-term residence intention					0.033	0.000	0.138	0.103	0.123	0.146	0.148	0.086	0.176	0.044
Network maintenance					-0.061	0.403	-0.037	0.597	-0.041	0.561	-0.049	0.502	-0.074	0.304
Communicate with young people					0.071	0.306	0.054	0.433	0.049	0.476	0.049	0.476	0.035	0.614
Social service willingness					0.076	0.308	0.017	0.819	-0.009	0.908	-0.092	0.904	0.009	0.909
Access to social participation channels					-0.035	0.610	-0.040	0.556	-0.050	0.465	-0.049	0.482	-0.445	0.522
The need to interact with people					0.004	0.951	0.017	0.784	0.015	0.820	0.108	0.870	-0.007	0.914
Participate in cultural and sports activities					0.108	0.113	0.124	0.065	0.123	0.069	0.106	0.123	0.097	0.160
Event space demand					0.116	0.071	0.092	0.155	0.064	0.326	0.044	0.503	0.040	0.544
Willingness to participate in public affairs					0.014	0.838	0.043	0.531	0.021	0.773	0.106	0.888	0.004	0.954
Willingness to work after leaving the job					-0.048	0.551	-0.046	0.559	-0.061	0.446	-0.040	0.629	-0.028	0.721
Subjective perception of physical environment														
Overall environmental satisfaction							0.243	0.018	0.218	0.036	0.187	0.078	0.176	0.097
Surrounding environment satisfaction							-0.776	0.406	-0.052	0.575	-0.060	0.524	-0.059	0.529
Environmental satisfaction in the community							0.135	0.322	0.148	0.274	0.158	0.256	0.095	0.498
Satisfaction with building environment							0.030	0.786	0.015	0.892	0.013	0.909	0.027	0.811
Satisfaction with housing environment							0.075	0.427	0.055	0.568	0.056	0.567	0.056	0.564
Subjective perception of social environment														
identity of neighborhood mutual assistance									0.022	0.762	0.050	0.500	0.068	0.370
number of acquaintances in the community									0.019	0.799	0.206	0.780	0.015	0.842
sense of community belonging									0.049	0.477	0.053	0.444	0.050	0.474
trust of community residents									-0.033	0.651	-0.037	0.614	-0.046	0.527
trust in the subdistrict office									0.251	0.003	0.245	0.004	0.230	0.008
Activity duration											-0.010	0.890	-0.014	0.848

(Continued)

TABLE 3 Continued

	Model 1 (empty model)	Model 2 (adds control variables)	Model 3 (adds personal active life ability)	Model 4 (adds subjective perception of the physical environment)	Model 5 (adds social environment perception)	Model 6 (adds the activity duration variable)	Model 7 (adds objective evaluation variables of the physical environment)
Fixed effects	H-3					0.382	0.320
	O-2					-0.003	0.972
	O-3					-0.143	0.076
Objective material environmental quality	Environmental quality around residential areas						0.321
	Inner environmental quality of residential area						0.385
	Housing environmental quality						-0.413
	The connection between residential areas and cities						-0.453

research institutions in China are paying more attention to solving the elderly care problem through the development and construction of large-scale comprehensive elderly care communities. They believe that this development method can solve the space competition among residents of different age groups, and the construction scale should not be limited (50). Although these new communities integrate multiple service facilities such as nursing institutions and senior housing, this study found in the survey that these “senior cities” tend to charge higher fees, generally above 6,000 yuan/month, and the highest retirement salary of the elderly living in old residential areas is 3,000–4,000 yuan per month, which is far beyond their financial ability. At the same time, whether it is beneficial to the physical and mental health of the elderly to isolate them in large suburban elderly communities requires further discussion.

In addition to the disabled elderly who are a very important group of elderly people to pay attention to in the process of home care, numerous “young” elderly people in China are fully capable of taking care of themselves. The study found that the elderly in the residential area sample have a high degree of dependence on the environment of the older neighborhoods and are willing and actively involved in the regeneration of the residential environment and community public affairs. Therefore, in the future renovation of older neighborhoods, renovation rather than complete demolition not only meets the requirements of sustainable development but is also of great significance to the protection of urban architectural culture. Older neighborhoods and the elderly are in a process of mutual adaptation and matching (51, 52). For the elderly, a familiar environment is the cornerstone for them to maintain their daily living abilities and a healthy mental state. In the process of regeneration, special attention needs to be paid to a “degree”. Necessary technical means must be used to improve the living environment of the elderly. At the same time, in the physical and social environment, they must also maintain their familiarity with the environment and protect the existing built environment of these cities to a certain extent. In general, the application of the EPA-S model to neighborhood regeneration from the perspective of the whole life cycle requires planning, design, organic regeneration, use, and management. In the whole process of assessment, urban design methods from economic, environmental, social, and governance dimensions are comprehensively applied (53) to maintain a dynamic matching relationship between the elderly and environmental places and improve the vitality of both.

Compared with the in-depth exploration of active aging implementation paths in European and American countries, China’s research and practice in this field has just begun, and there is still a lack of sufficient theoretical foundation and empirical evidence to support the improvement of relevant planning standards and policy mechanisms. From the contents of the 2021 “National Demonstration Age-Friendly Community Rating Rules” and the 2022 “14th Five-Year Plan for Healthy Aging”, it can be found that the existing planning policies and technical standards pay more attention to the construction of service system to ensure the health of the elderly and the transformation of community suitable for aging based on barrier-free design, and less to the spiritual content such as promoting

social activity emphasized by active aging. In addition, the relevant technical standards or design guidelines issued by the Ministry of Housing and Urban-Rural Development to guide the regeneration of older neighborhoods in the past two years also lack differentiated update measures for different types of residential areas. The index system constructed in this study based on the EPA-S model can be used as an evaluation tool to analyze the residential environment characteristics of urban “double aging” neighborhoods under the active aging framework, and then identify the residential objects that urgently need to be updated based on the problems, optimizing the existing spatial update plan and implementation mechanism. At the same time, this tool can also be used as an effective means to evaluate the age-friendliness of double-aging neighborhood environments, from micro to macro, providing a reference for the formulation of policy frameworks for age-friendly communities and cities.

## Conclusion

Based on the literature review, this study proposes discussion and research based on the EPA-S theoretical analysis framework and selects different communities for empirical investigation to prove the importance, policy value, and significance of strengthening the community elderly care model. This paper analyzes the model through the multi-layer linear regression method. The results show that the EPA-S model can be used as a tool for the evaluation of “double aging” residential renewal. At the same time, the analysis results of each variable also provide a scientific basis for the aging-friendly regeneration of residential areas, and it is summarized as three updated implementation suggestions: ① In the process of residential area renovation, the material space environment assessment content and questionnaire content under this model can be used to investigate the aging of the physical environment of double-aging neighborhoods. And then formulate and improve relevant transformation policies based on the specific conditions of the environment and the elderly; ② The analysis results of the multi-level linear regression model indicate to a certain extent that the goal is to promote active aging and ensure residents gain health and happiness. The targeted residential renewal process needs to pay attention to the differences between the elderly groups and promote the improvement of individuals’ active living abilities with participation in community cultural and sports activities as an important content. It should give more play to the role of the street level in the neighborhood regeneration, improve the quality of roads and public activity places in and around residential areas, and provide facility support for basic living and home-based care services for the elderly within the community scale. ③ Based on the conclusion obtained in this study that personal active living abilities are closely related to the mental health of the elderly, it is necessary to further explore the deep-seated reasons that affect the development of their active living abilities and establish a path framework for multi-dimensional urban design intervention, including spatial strategies, policy mechanisms, etc. In addition, it

should be pointed out that this study mainly used questionnaire interviews in the elderly sample survey to watch exhibitions in outdoor public spaces and did not cover more elderly groups who mainly live indoor activities due to their physical disabilities and other reasons. Therefore, in the future, it is necessary to further expand the scope of the elderly sample group and enrich the understanding of the relationship between the residential environment and the mental health of the elderly.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

## Ethics statement

The studies involving humans were approved by Architecture School, Tsinghua university. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

CM: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Software, Writing – original draft, Writing – review & editing. GC: Data curation, Investigation, Methodology, Software, Visualization, Writing – review & editing. BL: Conceptualization, Funding acquisition, Project administration, Resources, Supervision, Validation, Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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